Climate change and the concept of Integrated Urban Water Management

Aggeliki Marinou

SCHOOL OF ECONOMICS, BUSINESS ADMINISTRATION & LEGAL STUDIES

A thesis submitted for the degree of

Master of Science (MSc) in Environmental Management and Sustainability

January 2019

Thessaloniki – Greece

Student Name: Aggeliki Marinou

SID: 1105170008
Supervisor: Dr. Alexandra Michailidou

I hereby declare that the work submitted is mine and that where I have made use of another's work, I have attributed the source(s) according to the Regulations set in the Student's Handbook.

January 2019
Thessaloniki - Greece

Abstract

This dissertation was written as part of the MSc environmental management and sustainability at the International Hellenic University. This paper aims to infer climate change impacts in water sector and specifically in urban water sector. It is focusing at issues that global warming causing in cities in water management. Water quality, water supply and sanitation are serious problems because of climate change.

A good integrated water management for urban areas is necessary. Integrated urban water management is a modern approach to help cities deal with water issues. In this paper is presented the concept of IUWM and the principles that IUWM uses in order to help cities. A case study has been conducted with the aim to provide cities that have already implement IUWM and city that will use it in the future.

Keywords: integrated urban water management, climate change, water quality, water supply, sanitation, reused water, storm water management, waste water management

Aggeliki Marinou

31/1/2019

Preface

First of all, I would like to thank my supervisor Aleksandra Michailidou who helped me providing me with all the necessary information and knowledge about my dissertation. I would like to thank my family and my friends for the support and of course my colleges.

Contents

TABLE OF ILLUSTRATIONS

TABLES

1. Introduction

1.1 Climate change and Integrated Urban Water Management

In our days climate change is the most challenging issue concerning the whole world. It is a fact that the annual surface temperature of earth's atmosphere is increasing because of the large concentration of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), CFCs and nitrous oxide (N_2O). The primarily responsible is the human activity through combustion of fossil fuels and deforestation. The phenomenon of climate change is obvious through a numerous of examples such as the quickly collapse of Larsen B ice shelf in Antarctica (Bulkeley, 2013). The degradation in hydrological cycle and aquatic systems is happening. Climate change has impacts in many sectors. One of the most serious impacts is in water sector (Murray et al., 2012). Specifically, potable water in cities faces many challenges. Freshwater from sources is scarce, other sources to be treated are costly and wastewater is increasing. In many regions people have to deal with poor quality of water provoking them illness issues. People are increasing and water resources are altering. Because of this situation it is observed that water supply becoming less. Water supply technologies face r damages because climate change influences these technologies. Thereby sanitation of a city can be influenced too.

Climate change will induce more extreme weather events such as flooding and drought. Water is in disadvantage position to suffer more. Cities have to deal with this problem. A water management system is needed in order to protect the available water for citizens. New methods are needed for cities to deal with the small amount of available freshwater. Water management is one of the greatest concerns of cities. The concept of Integrated Urban Water Management (IUWM) is suitable for cities facing water problems. IUWM is a strategic planning framework expert in identifying and emphasizing investments based on urban water management. This project is a better approach than the existing management systems in which freshwater, wastewater and storm water is components of a management plan and managed as lonely entities. IUWM is adaptable planning helping stakeholders in institutional arrangements,

economic analysis and modern economic solutions. It is a useful tool for cities since it protects the environment and maximizes urban attractiveness.

IUWM is a modern tool. Some regions have already implemented it on different levels and with diverse focuses according to every city needs. On the other hand, there are cities that have set the bases to implement it in future since they recognize the benefits that could provide to citizens.

1.2 Aims and objectives of the study

The study presents the relation between climate change and urban water issues through a literature review. The purpose of this research is to highlight the issues that cities have in water supply, water quality and sanitation. The second objective of this study is to point out the impact of water sector caused by great increase of climate change. An effective solution is vital to resolve the issue. This study aims to prove that by usage of the IUWM, can improve the current situation by offering a sustainable life. The study is focusing on the concept of IUWM analysing the water reuse, storm water management and waste water management. Furthermore, tables presenting real life examples of the implementation of the IUWM as well as of countries that initiate the procedures for the implementation of IUWM are included. Real life examples can help other countries to understand the benefits of using IUWM. The purpose for countries that have not yet implemented the IUWM is to consider applying it and then to conduct research on how to implement IUWM adapting it to the needs of every country.

It should be mentioned that this research is based on information and data from research papers available through specific databases such as Google Scholar, Science Direct and Scopus. The keywords which used were: climate change, integrated urban water management, water, reuses water, water supply, sanitation, water quality, storm water, desalination, and rainwater harvesting and wastewater management.

1.3 Structure of the study

The structure of the study has been formed in a way to present the issues through an understanding way. At the begging it is presented an introduction about climate change. Then it is referred the current situation about water quality, water supply and sanitation in cities. At the end of this chapter it is presents the relation between climate change and city.

At the second chapter it is presented the conventional urban water management and the integrated urban water management. Then it is following the section about adaptation measures referring water reuse, storm mater management and waste management. At the last section of this chapter are mentioned flexible and adaptable urban water systems such as the concept of SWITCH.

At last chapter is presented a case study which took place through a research of other scientific papers. A table is created in order to quote cities that have implemented integrated urban water management and cities that are going to use this project. The author's name, the date of the work, the name of city and specific tools of IUWM have been used or will be used, are presented in the table. The study ends with conclusions and recommendations.

2. Climate change in cities and water

In our days one of the most significant global issue is the change of climate. The ice is melting; the sea level rises, and many areas have to deal with extreme weather events such as extreme heat and droughts. (Bulkeley, 2013). Global warming is the phenomenon in which the mean yearly surface temperature of earth is increasing (Bulkeley, 2013). Human is responsible for the release of greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), CFCs and nitrous oxide (N_2O), due to burn of fossil fuels and deforestation. These human activities are increasing the greenhouse phenomenon and warming the earth (Chasek, et al., 2010).

Nations must collaborate in order to eliminate global warming (Chasek, et al., 2010). Some issues that have provoked intense debate regard actions in order to minimize GHGs. Global agreement is a difficult part. Global warming is not only a universal matter, but it is also a local matter. Cities play a significant role in politics of global warming (Bulkeley, 2013).

2.1 The role of climate change in water and water quality.

The challenge that word faces is the availability in freshwater in adequate quality and quantity. The freshwater obtains 2.5% of the world (Alcamo et al., 2007; Ercin & Hoekstra, 2014). Any changes in atmospheric temperature and in radiation balance are connecting with hydrological cycle. There are evidences such as melting of ice, increase of the air temperature and ocean's temperature which disclose the warming of climate (Bates et al., 2008). Economic activities of human and climate change threaten the amount of freshwater. Food security, environmental sustainability and economic development possibly will be affected in future because of the increasing rate of water scarcity (Alcamo et al., 2007; Ercin & Hoekstra, 2014).

It is obvious that lack of freshwater has impacts on societies and ecosystems (Murray et al., 2012). The past decades remarked that climate warming is related to changes in

hydrological system. For instance, it is observed changes in precipitation patterns, changes in soil moisture, escalating atmospheric vapour of water etc. (Bates et al., 2008). A large amount of population faces serious water scarcity problems. It is predicted that climate change is going to worsen water scarcity in a global scale. Large changes and universal shifts in precipitation patterns are possible to happen in hydrological cycles. Also, an increasing at the frequency of extreme events is possible. Wet areas will become wetter and dry areas will become dryer, causing less availability of water (Distefano & Kelly, 2017).

Poor water quality creates water scarcity problems and a limit on volume of water for much utilization is probable to be set. Degradation of environment is happening because of intensive agriculture, resource-heavy industries and bloom of urbanization. The storm water flow can transfer large amounts of pollutants and thereby provoke the minimization of water quality (Palaniappan et al., 2010).

Water quality parameters can be organized in three categories. The first category comprises of physicochemical basic parameters such as pH, temperature, and nutrients. The second category includes micro pollutants (inorganic and organic) including metals, pesticides and pharmaceuticals. The last category is the biological parameters with pathogens microorganisms, cyanobacteria and water quality proxies (Delpla et al., 2009). Microbes, heavy metals, organic chemicals and nutrients are the most usual water pollutants. Eutrophication is the biggest concern regarding water. Large amount of concentration of nutrients from agricultural runoff, domestic and industrial sewage and burn of fossil fuels and fires are responsible for eutrophication. Heavy metals from industrial and mining activities can accumulate in human body and in other organisms too (Bahri, 2012).

2.2 Water Supply and Sanitation

A large popotion of population in developing countries has to deal with water scarcity (Seckler et al., 1999). Because of increasig of people, there is a possibility for water

supplies becoming less since river and groundwater are altering. Many water sources are not any more useful for specific utilizations. The phenomenon of global warming can influence water supply technologies beause of some events such as flood damage. In the case of dry days roof rainwater harvesting and groundwater technologies will face problems (Bahri, 2012).

Water supply technologies are affected by cimate change. The first influence on water supply is that may change the frequency of low flows which means more floods. Also there are possiblities to change the credidibility of supply sunstructure, for instance converting the security of tank. Furthermore, it may change the capacity to use raw water to drinkable standars. At last, it is possible to change the requirement for water and the opportunity to deliver water to satisfy consumers needs (Arnell et al., 2006).

It is a fact that 4 out of 10 people globally had access to improved sanitation (World Health Organization, 2006). One significant target is to minimize by half the number of people with inadequate water sanitation (Mara, 2003). There is a connection between water quality and sanitation. It is a fact that poor sanitation can cause water contamination. In many regions the sewage and human waste are responsible for water contamination (Moe & Rheingans, 2006).

The operation and maintenance of water-dependent sewer systems will be difficult in dry regions. Because of climate change an incerase of the intesity of rain and flood are a possible senario. Sewsers may be damaged because of the intensity of flood (Bahri, 2012). It is possible floods deluge treatment facilities and create problems in human health (Tucci, 2009). Furthermore flood may provoke respitory problems to citizens because of the contamination of water supply (Habitat, 2011).

The obstacles to achieve water and sanitation for all people are many. Many developing countries because of economic problems cannot invest in sanitation. Also the little prioritization of water and sanitation is a reason to limit the maintenance and the expansion of services. Corruption and inefficient management can enhance the problem of poor sanitation. The absence of water quality standards and the problem in

imposing standards also contribute to set obstacles to improve health conditions. Many countries have the standards but have to deal with other problems such as the lack of personnel. Policies and investments are the answers to overcome the obstacles (Montgomery & Elimelech 2007).

2.3 Climate change in cities

Cities play an important role to handle the global warming issue. There are four reasons to identify the relation between cities and climate change. To begin with, it is known that cities consume large volumes of energy and generate large amount of waste. Local authorities affect the processes of energy consumption and waste production. The variety of these processes, vary depending on national circumstances. Then local authorities are responsible to maintain sustainable development through the implementation of Local Agenda 21 with the aim to defeat climate change. The third reason is about the effect that local authorities have to others with the target to minimize the global warming issue. Local authorities can persuade international governments to take action and also local authorities can develop projects in order to manage GHGs. Finally, local authorities are experienced in dealing with environmental impacts and some of them have undertaken modern actions in order to minimize the impact of GHGs on global warming (Bulkeley, 2013).

Global warming affects river regimes, flow speed, water levels, alteration in wet places (Whitehead et al., 2009). In recent years it is observed an increase in water pollution because of human activities. It is an important issue to protect quantity and quality of water sources (Iglesias et al., 2007). The effects of global warming are obvious in freshwater at urban areas. Cities must deal with water issues through adaptation and mitigation measures and also specific plans are adopted with the aim to protect water (Bahri, 2012).

3. Integrated Urban Water Management (IUWM)

In our days people choose to live in cities (Fattahi & Fayyaz, 2010). An integrated approach is needed with the acceptance of all stakeholders in order to manage urban water since the managing of water and wastewater can help to meet water demand and the protection of the environment (Bahri, 2012).

The water management is a huge concern for many cities (Bahri, 2012).Each city must develop tools in order to help governments to know how water is available in every place,how it is used and how they can suppot water services in next years. The balace between water demand and supply is crucial (Fattahi& Fayyaz, 2010). Water from pure sources is scarce and the quantity of wastewater becoming more and more. Lack of good quality of water is a common phenomenon in cities and many citizens become ill because of that. A disruption in hydrologic and aquatic systems is observed (Bahri, 2012).

The situation will become worse because of climate change. Degradation of the environment is a huge concern since extreme weather events are possible to cause damage in urban water infrastructure (Bahri, 2012).

A promising approach, in order to create a better situation, is Integrated Urban Water Management (IUWM). In that approach isolated entities are responsible to manage water supply, sanitation, storm water and wastewater. IUWM's goal is to succeed sustainability in economic sector and protect the environment (Bahri, 2012).

3.1 Conventional Urban Water Management

Urban Water Management set some goals. To begin with, it quarantines access to water and sanitation infrastructure and services. Urban Water Management is able to manage rainwater, wastewater, and storm water drainage and runoff pollution.

Furthermore it can control waterborne diseases and epidemics and reduces the risk of water-related hazards, including floods, droughts and landslides. Water management must be done in a way to avoid resource degradation. Conventional urban water management strategies try to find a way for a better wastewater treatment, sanitation, drinking water and other water related services. It is a fact that many cities have to deal with water shortages and changes in water quality (Bahri, 2012).
Unfortunately conventional urban water management strategies have failed to fulfill the necessary demands that any city have. Because of climate change and urban growth, conventional urban water management seems out of date (Bahri, 2012).

The way that water supply, sanitation, wastewater treatment, storm water drainage, and solid waste management have been planned was specific in order to be treated as isolated services. The traditional urban water management model was not in a position to detect different water qualities and also could not have the capacity to recognize water uses for them. “As a result, high-quality water has been diverted to indiscriminate urban water needs” (Bahri, 2012).

3.2 General information about Integrated Urban Water Management

Integrated Urban Water Management (IUWM) is a significant and crusial issue that all countries have to deal with (Fattahi & Fayyaz, 2010). IUWM is a significant tool since it constitutes of principles that provides a better coordinated, reacting well and sustainable resource management practice. Water sources, water use sectors, water services and water management scales belong to the concept of IUWM (Bahri, 2012). IUWM is an important tool for urban water services because it can reduce their environmental impcact, make their contribution greater to social and economic life of cities and all that could happen through planning and managing of uban water systems (Whitler & Warner 2014).

Efficiency, equity and environmental sustainability are three approaches that an IUWM demands. The first approach, efficiency, is about the requirement to make the best

effective use of a susceptible and an infrequent resource. The second important approach is equity which refers in the way that water could be available to all socioeconomic groups, so that groups could have all the elements to have a sustainable wellbeing. And finally the third approach, environmental sustainability, implies management in which protects the ecosystems and guarantee sustainability for the new generations (GWP TAC, 2000). Unfortunately, there is no exists always a harmony between these three approaches and a scenario of conflict is possible. Central governments play a significant role to sustain harmony between the three approaches through legislation in order to create a framework for water distribution (UNDP, 2006).

Bahri (2012) states that IUWM is significant because:

- It can find alternative water sources.
- It can find the qualities and the utilizations for water sources.
- It consider water storage, distribution, treatment, recycling, and disposal as part of the whole resource management cycle.
- It tries to protect, conserve and exploit water at its source.
- It is responsible for non-urban users that are dependent on the same water source.
- It adjusts the institutions (organizations, legislation, and policies) and informal practices (norms and conventions)
- It understand the relationships between water resources, land use, and energy.
- It provides economic efficiency, social equity, and environmental sustainability.
- It wants the participation by all stakeholders.

Unfortunately, there is no model that can be used to every single case and there is not only one method that can be used sufficient. The combination of approaches can indicate local sociocultural and economic conditions. Small and mid-sized cities (less than 500.000 inhabitants) belong in advantageous position in which IUWM has bigger opportunities to succeed its purpose (Bahri, 2012).

Integrated Urban Water Management is a new approach that every city needs it (Bahri, 2012). The IUWM is based on scientific prospect of water services. Universal and regional agencies ended in that new approach because the problems of waste disposal, water reticulation, urban storm water, etc. must not be regarded to be standalone subjects (Fattahi & Fayyaz, 2010) IUWM is significant since it creates new relationship to water of city and more different kind of resources, and set the basis on ways that the authorities could check the issues (Bahri, 2012).

Table 3.2.1 The differences between urban water management and IUWM. Adopted from :Bahri, 2012

Past urban water management	**Future IUWM**
Rainfall records are significant since water and wastewater systems have set its basis on them.	Water and wastewater are based on data and techniques that can help the problems about uncertainty and variability.
Water's path is only one use, to treatment and disposal.	Water can be taken back and used many times.
Storm water is a problem that must be transferred from urban areas.	Storm water can be used to be harvested as a water supply and leached or maintained to other uses such as vegetation.
Human waste is a trouble to deal with.	Human waste is important since it can be used as a fertilizer.
It is used linear approaches in order to gather, treat, use and eliminate water.	It is used restorative and regenerative approaches in order to have systems to supply water, energy which has a connection with the land-use design, regulation and health.
Demand is equal to quantity. Infrastructure is based on the amount of water required or made by end-users.	Demand has many sides. Infrastructure suits the characteristics of water or produced for end-users.

Gray infrastructure includes metal or plastic.	Green infrastructure has soil, vegetation, concrete, metal and plastic.
As bigger as better. Collection system and treatment plant are all together in the same place.	Not big is possible. Collection systems and treatment plants have the opportunity not to be all together.
Typical solutions restrict difficulty. Water infrastructure has been developed by urban water experts.	Solutions may be various and flexible. A broad range of professions are responsible for management strategies.
Utilities are responsible on accounting and to keep an eye on costs.	Utilities are responsible to assess the benefits from any investment takes place and concentrate on value creation.
A business-as-usual toolkit is the standard.	An expected toolkit of options has high-tech, low-tech, and natural systems.
Institutions and regulations set obstacles in modernization.	Institutions and regulations motivate new measures.
Water supply, wastewater and storm water systems are distinguishable.	Water supply, wastewater and storm water systems are on purpose connected. There is physical and institutional completion through coordinated management.
Collaboration is in the scale with public relations. The involvement from agencies and public takes place when it is required an agreement of predetermined solution.	Collaboration is in the same level of engagement. Agencies and public participate in order to find a solution.

3.3 IUWM adaptation measures to deal with climate change

IUWM includes a range of goals and measures with the necessary technology and financial basis. Even though, every city requires different water management practices, and the target is in global scale. IUWM provides cities with a modern framework for

planning, designing and managing urban water systems (Bahri, 2012). Cities must have the apportunity to deliver water in good quality and in appropriate quantity without provoking the degradation of water resources. Furthermore, cities must be supporters of efficient water use and utilization of alternative water sources.

3.3.1 The role of water reuse

Water reuse is growing in countries that face problems with scarcity, but also, it is observed that countries that do not have serious water scarcity problems are aldready in favor of this practice. US, Western Europe, Australia and Israel are countries that water reuse is in progress (Miller, 2006).

Every region has a different word to describe the reused water, for example in US it is called recycled water and in California and in Florida it is called reclaimed water. WateReuse Association makes a combination with words: water reuse, recycling, reclamation and desalination in order to find the definition. The definition that WateReuse Association provides is “the reclamation and treatment of non-traditional (or impaired) waters for the purpose of beneficial reuse. Non-traditional or impaired waters include the following: 1. municipal and industrial wastewater effluent, 2. brackish water, 3. poor-quality ground water, 4. agriculture return flows, 5. Storm water and 6. Oceans” (Miller, 2006).

The significant elements that every sustainable urban development strategy needs are reclamation and reuse. Used water is handled and gathered in many ways for reuse in many sectors such as agriculture and industry (Bahri, 2012). In some areas the use of recycling water with the aim to upgrade food production is a famous approach. The benefits that farmers succeed using wastewater for irrigation are huge since it is free and accessible. Wastewater contains nutrients and it is a good solution for farmers to avoid chemical fertilizers. Farmers, traders and others who are involved with agricultural life, are affected by the use of wastewater since it supports their income. The use of wastewater combines the public health and the environmental protection when at the same time offers an agricultural lifestyle (Bahri, 2012). There are many

examples in which strawberries, grapes and others are irrigated with reused water. In addition, there are many examples of using potable reused water globally like, NEWater facility in Sigapore and facilities in Orange Country in California (Miller, 2006).

One of the first applications of reused water was for irrigation of golf and landscapes (Miller, 2006). Parks, green spaces, golf courses are irrigated by wastewater. Wastewater can contribute to return water bodies and wetlands (Bahri, 2012). Another application of wastewater is in industrial sector. Industrial sector uses wastewater in cooling towers, for boiled feed and also it plays significant role in the use of cooling cycles of power plants (Miller, 2006). Technological innovation is the key factor that recycled water can be used. Modern membrane and new nanotechnologies help the reclaimed water to be efficient and also potable (Bahri, 2012).

Water reuse is a sustainable solution for the challenges that urban, industrial and agricultural sectors face in our days. Water reuse has many benefits. At first it is a sustainable way for water supply. Reclaimed water uses not such energy as importing water. Then it is important that local authorities have the control of supply. Recycled water minimizes the quality of treated wastewater that allows flowing out from sensitive or impaired surface waters (Miller, 2006).

The utilization of wastewater reuse methods around the world have shown that reclaimed water is a modern alternative resource. Reclaimed water can bring a modern approach to water management which is the integrated resource management with water reuse containing waste water management. This method helps to deal with water demand and supply, and wastewater disposal and the protection of the ecosystem. Water management wants to succeed more sustainable development for the whole world (Lazarova et al., 2001).

Countries that want to implement integrated water management should consider all the parameters of the following alternative solutions: “1) developing any undeveloped water resource, involving desalination of brackish or water of the sea, 2) wastewater management and reuse, 3) inter-basin removal, 4) more productive irrigation systems,

5) minimize water leakage, 6) usage of adequate changes for water and 7) inserting water from neighboring countries." The most cost-effective ways to deal with the issue of water scarcity are to improve efficiency of the water usage and to minimize waste. However, improved wastewater systems are vital for the success of affective results for this issue (Lazarova et al., 2001).

There are two main types of reuse which have been developed and applied in the word. The first type is potable uses, which is direct or indirect and the second type is direct or indirect non-potable uses in agriculture (Lazarova et al., 2001).

With the right technology, any water quality required by the citizens can be successful. There is a variety concerning the costs and that makes the choice of the best technology a sensitive issue. A reuse project is efficient with the proper planning and by unifying water reuse in the water management systems. New tools, such as integrated technical-economic models and decision-making tools are needed in order to succeed integrated water management and planning. One of the challenges to water reuse systems is how to succeed a fine level of operational reliability, not only of process facilities but also of storage reservoirs and distribution networks (Lazarova et al., 2001).

3.3.2 Storm water management

Storm water is responsible for the degradation of waterway environments in a city, due to the changes in stream flow and water quality (Brown, 2005). It is known that human activity in urban places creates wastes and pollutants on the surfaces and it is possible that these are washed out in water systems when a storm occurs. The need to build drainage systems is huge since it is way to ensure for public health. Storm water is the main reason that great amounts of contaminants end up to receiving waters, therefore storm water is responsible for water pollution in many places (Barbosa et al., 2012). The aim of the management of the traditional urban storm water drainage

system is to reduce the risks which relate to flooding in urban environments (Brown, 2005).

Storm water can transfer organic and inorganic pollutants. Hvitved-Jacobsen et al., (2010) categorized them in six groups: solids (suspended solids, SS), heavy metals, biodegradable organic matter, organic micro pollutants, pathogenic microorganisms and nutrients. This approach is the simplest. There are more pollutants identified in storm water and it is possible that they cause the same impacts in water (Barbosa et al., 2012).

Season and land use are mentioned as two factors that affect the storm water characteristics. It is important to record at national and regional level the qualitative and quantitative characteristics of storm water, because site specific, climatic and other variables play a significant role. Precipitation washes and removes the pollutants and thereby the quality of flow is detected by the amount, frequency, intensity, duration and pattern of precipitation (Hvitved–Jacobson & Yenisei, 1991). Precipication can pose quantity and quality water problems especially when storm water is discharged to water systems without any management of storm water (Barbosa et al., 2012).

The appropriate attention on storm water management must be given to water quality and to erosion and flood control. These processes affected in a large degree by urbanization (Barbosa et al., 2012).

Since 1980 modern management systems and approaches have been implemented in order to develop a better urban storm water environment. The results appear in the design, testing and scientific verification with the goal to improve different kind of storm water techniques in the existing areas and also in the new areas. Unfortunately, because of many factors there are limited implementations of innovative integrated urban storm water management (IUSM) (Brown, 2005).

During the last years the concept of the Integrated Urban Storm Management has faced a rapid evolution. The idea is to create an integrated urban water management in order to obtain valuable water resources. General it is an idea which aims to a sustainable management of storm water. Demand management, clean production and education innervations are concepts that must be considered to succeed minimization of water consumption and a better prevention as concern the pollution (Brown, 2005).

Storm water management is significant since it can mitigate the fall of rain and help the improvement of water sources. Flooding is a serious problem for many countries. Some options to solve this kind of problem are to use retention ponds, permeable areas, infiltration trenches and natural systems to mitigate water. Also, green roofs are an excellent solution to mitigate rainfall. Green areas use ecosystem services in low budget in contrary the conventional storm water drainage systems (Bahri, 2012).

Chocat and others (2001, p.63) introduced goals for a sustainable integrated urban storm water management, such as flood reduction-minimizing peak storm water discharges from urban catchments, pollution minimization by preventing, collecting and/or managing pollution loads, storm water retention-harvest and beneficial reuse of rainwater and storm water runoff within or near the urban catchment, urban landscape improvement showing rather than hiding water by functionally incorporating storm water into urban streetscapes and green areas and, reduction of drainage investments innovative integration of storm water systems into the urban environment for reducing the cost of infrastructure. The general goal is the creation of an integrated urban water system in order to sussed sustainability and there are possibilities to happen whether stakeholders and community work together (Brown, 2005).

3.3.2.1 Rainwater harvesting

It is known that rainwater transfers small pollutant loads which are contingent on location, materials of roofs and the construction of collection system. Rainwater

harvesting system has three segments which are the collection system, the conveyance system and storage system. The disadvantage is the unforeseeable supply which many times needs a huge storage place. Gentle treatment and disinfection is sufficient for rainwater management to non-drinkable standards (Makropoulos et al., 2008). Water harvesting developed with the aim to be used for a simple usage but in our days has a more important role because of the fact that can help water supply for domestic use and in agriculture. Geddes was the first to define water harvesting as "the collection and storage of any farm waters, either runoff or creek flow, for irrigation use" (Boers et al., 1982).

Water scarcity in households is a problem which can be addressed through rainwater harvesting. The implementation of rainwater harvesting may be easy and effective in relation to the section of cost. Another important element about rainwater harvesting is that flow or roof harvesting allow water supply to have a direct way, and at the same time can help ground to obtain again water while reducing the possibilities of flood. That kind of measure is a solution for making improvements in water supply and drainage. It is vital to create an evaluation system concerning the design criteria, costs and impacts in order to obtain a general idea about how to implement appropriate rainwater harvesting systems (Bahri, 2012).

3.3.2.2 Desalination

The three quarters of the earth's surface are veiled by water, but only 3% of water is potable. Many countries have to deal with serious water problem because there are lack of quality and quantity of fresh water. Water desalination can be the solution to this problem (Karagiannis & Soldatos, 2008).

In recent years desalination has obtained huge potential. Desalination is a method in which water can be used again when salt is removed in order to become potable or to be used for other utilizations such as oil refinery boiled feed water (Miller, 2006). The past two decades the economics of desalination have changed because of innovative

technology in membranes. The cost of this method is more accesible now (Bahri, 2012). In our days desalination is a significant part of water supplies. Desalination is not only about ocean desalination. In the US an icreasingly practice is the desalting saltish groundwater (Karagiannis & Soldatos al., 2008). Countries that have a depletion of renewable water resources, the method of desalination covers the need for potable and industrial demand. Unfortunately, in the sector of agriculture the use is poor, but an increasingly support in cultivation of high-value crops in greenhouses is observed (Bahri, 2012).

There are two categories of desalination systems. The fisrt category is about the use of convential source of energy and the second category is about renewable energy sources such as solar. The use of the first desalination system is much lower regarding the cost (Karagiannis & Soldatos, 2008). Desalination technologies can contribute to secure a sustainable and safe water supply for everyone (Miller, 2006).

3.3.3 Wastewater management

Wastewater has a different meaning to every people and the numbers of definitions are huge. One of the definition of wastewater that suits better is “waste water is a combination of one or more of: domestic effluent consisting of black water (excreta, urine and faecal sludge) and grey water (kitchen and bathing wastewater), water from commercial establishments and institutions, including hospitals, industrial effluent, storm water and other urban run of, agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter” (Corcoran, 2010).

It is known that citizens in urban areas consume and generate great volumes of wastewater (Corcoran, 2010). Wastewater systems must be friendly to environment with the aim to give fresh water capable to be used and must remove wastewater from people and avert storm water to cause damages from flooding (Hellström et al., 2000). Wastewater management can be used accordingly to economic development and government’s ability of urban region. Local, regional and national authorities are

responsible to provide wastewater systems. Wastewater management is a team work and whether everyone understands that, then the benefits will be obvious (Corcoran, 2010).

The absence of efficient systems in order to manage wastewater has awful results in the pollution of water and in health (Parkinson & Tayler, 2003). A contiguous governance formation, economic and scientific expediency are the elements that are necessary with the purpose to develop wastewater treatment. People in cities have handled big amount of water in rainy seasons. Centralized wastewater treatment must me managed in order to deal with extreme weather. The building and maintenance of these systems and the dependency on frequent supply of water may be costly and not friendly to environment for small and medium size developing countries. Planners are focusing in decentralized systems in which wastewater is used near to places it is generated. Cities with natural hazards may found useful that systems. The system can use a small amount of water or no water and it is easy to be utilized by communities (Corcoran, 2010).

3.4 Flexible and adaptable urban water systems

SWITCH is a European Framework VI project which could meet the challenges that mentioned above. It is a five-year research project and SWITCH's applicability started in April 2006 on how "Sustainable Water Management Improves Tomorrow's Cities' Health" (Kayaga & Smout, 2008), (p12). SWITCH develops decision support tools and in order to help city's stakeholders to assess and investigate future possible options for IUWM (Mackay et al., 2010). SWITCH's goal is to provoke a change in urban water management through the development, application and demonstration of scientific, technological and socio-economic solutions. This project's target is to achieve a sustainable and effective urban water management (Kayaga & Smout, 2008).

A new change in flexible sanitation systems is observed. The change is from centralised mixed systems to decentralised systems which set the basis on the control of sources,

single usage of concentrated and dissolved wastewater which come from houses. The utilization of natural systems is becoming more preferred (Bahri, 2012). Natural systems are more adaptable to applications and have improved renewal opportunuties (Bahri, 2012).

4. Real life examples of Integrated Urban Water Management

The concept of IUWM is significant for many countries. IUWM is a comprehensive approach to urban water services such as water supply, drainage and sanitation. Some countries had the opportunity to implement IUWM and other countries have set the basis with research aiming to utilize the principles of IUWM in future.

4.1 Progress of IUWM

It is important to reach the goal of water and sanitation for everyone until 2025 (Mara, 2003).2Billions of people will have access to improved water supply and another large proportion of people better sanitation. This should be achieved with sustainable, low cost and simple technologies.

The year 2005 was the start of the “International Decade for Action: Water for a life”. A new attempt to succeed the Millennium Development Goals (MDGs) in order to minimize the world population with sustainable access to potable water and sanitation by 2025 had started. Moe and Gheingans in (2006) advocated that new attempt. Specifically, they referred that economic resources and sustainable technology are significant to meet the MDGs. The two authors reviewed five challenges to succeed potable water and sanitation international. The same year Arnell and Delaney recognized that the impacts of the climate change in the water industries are huge. They focused on the assessment of the ways in which water supply industries in England and Wales had been adapted to global warming.

An international water model was utilized with the aim to analyze the impacts of the global warming, and social and economic forces on future global water stress. Alcamo

et al. (2007) analyzed the global water model, computed and compared three different indicators for water stress with the goal to address the uncertainty of water stress. Montgomery and Elimelech (2007) presented their work about water and sanitation in developing countries including the parameter of health. They mentioned the obstacles in order to succeed water and sanitation for everyone and suggest ideas to overcome the challenges.

There is much evidence that freshwater resources are affected by global warming provoking consequences to human environment and ecosystem. Bates B. et al. (2008) presented that issue mentioned analytically the climate change and water. They focused on recent water changes from global warming and predicted the future changes. In addition, Bates et al. (2008) presented the climate change impacts on the whole world. As water resources are exhausted, desalination of seawater becomes an interesting idea. At the same year Karagiannis and Soldatos (2008) focused on categorizing the related publications about desalination methods and sorted them in an organized method with the aim to allow important comparisons and draw helpful conclusions.

The consequences of climate change on water quality have started to be studied. In 2009 Delpla et al. gathered all the recent literature and tried through a review to propose a synthesis of them. They presented the climate change effects on water quality and they concentrated on two important points. The first point was about the impacts on water quality sources and the second about the expected impacts on potable water production and the quality of water supply.

Another problem that many cities face is water management. Fattahi and Fayyaz (2010) introduced integrated urban water management. There were many goals and criteria that must be considered in the use of IUWM. Fattahi and Fayyaz (2010) in their article presented a mathematical model with the objective to optimize the problems about IUWM. They focused on three points which were the cost of water distribution, leakage water and the level of citizens' satisfaction.

Two years later Bahri (2012) presented her work about integrated urban water management. Bahri mentioned the status quo about the potable water scarcity and

the problems that cities have to deal with poor water quality. An analytical description about IUWM was presented including the effects of climate change, the role of government and stakeholders, and the necessary management strategies to implement IUWM. The same year Barbosa et al. (2012) reported the problems for a sustainable urban storm water management. Storm water is responsible for water quantity and quality because of the transportation of waste and pollution. Barbosa et al. (2012) presented a document with the aim to contribute to sustainable storm water management, mentioning the factors that should be estimated.

One year later, Bulkeley and Betsil (2013) provided an analysis of the role of cities handling with climate change and the idea of a sustainable urban life. Cities can create modern solutions to climate change since cities are the main producers of greenhouse gas emissions. Bulkeley and Betsil's book focuses on how international environmental governance and urban sustainability can be combined. This book is also presented a case study which examines the implementation of local climate change policy.

4.2 Characteristic of the examined places

The purpose of this chapter is to present 10 real life IUWM implemented systems and 8 that prepare themselves for future implementation of IUWM. The regions that have implemented or planning to implement IUWM are Adelaide in South Australia, Brisbane in Queensland, Sydney in New South Wales, New Castle in New South Wales, Albury in New South Wales, Melbourne in Victoria, Seychelles in East Africa, Municipality of Marondera in Zimbabwe, Kinshasa in Democratic Republic of Congo, Cape Town in South Africa, Accra in Ghana, Masindi Town in Uganda, Rotterdam in Netherlands and Windhoek in Namibia. These countries up to now present examples for IUWM implementation for other countries. For that reason, it is significant to present characteristics of places and explain the current water situation and also explain why these places utilize or want to utilize the principles of IUWM.

The last two decades Africa's growth of population has presented a rapid evolution. It is expected to become more. Africa's urban growth is happening in medium-sized cities and in small settlements. The number of slums is huge and that results in urban poverty and rise of inequality. It is a fact that in the whole world the greatest slum population is in Africa. These regions suffer from water supplies, sanitation, solid waste management and electricity problems. Water stress and water insecurity lead to extreme pressure on urban water management. The demand for water and water scarcity create pressure on water resources which means inadequate water supply system to provide good quality and quantity of water. Below 7 African cities are examined (Bahri et al., 2016).

To begin with, Masindi is a small town in Uganda near to Kampala. The population of city is approximately 45,400 citizens. The climate is favourable, and the annual rainfall is approximately 1,304 mm. There is lack of sewage system and the disposal of wastewater is realized through on-site sanitation. Lake Kiyanja is the main water resource of the town. A large proportion of city lies within the catchment. The degradation of catchment becomes is owed to cultivation, use of fertilizers and pesticides, overgrazing and the cut of trees. The consequences of degradation on lake water are huge **(**Eckart et al., 2011).

Cape Town is the capital of South Africa with population approximately 3, 5 million making it the second most populous city in South Africa. The city's contribution to national gross domestic product is 11%. Cape Town is an example of an African big city with an urban water system with good standards, but on the other hand the city is facing problems because of high population growth and mature infrastructure. The available water resources cannot satisfy citizens 'demand. In the future, people who live in the city will face water problems. Management of urban water systems in the town is challenging (Eckart et al., 2011).

Accra is the capital of Ghana and the population is approximately 2 million citizens. Accra is the largest and the fastest growing city. The water demand of the city does not connect with water production. The suburbs of Accra and new development areas face

problems with the connection in networks. Only 45% of citizens have access to water from their houses. Also, some amount of wastewater is used for irrigation in urban agriculture and solid waste collection is unstable (Eckart et al., 2011).

Windhoek in Namibia has population approximately 350,000 citizens. The increase of population is a serious matter for the city. It is an arid country with hot and dry climate. There are rivers in north and south sides. The 70% of residents have access to water supply. The water supply to connected citizens is in good quality. Extreme weather events such as droughts have serious impacts on city and provoke damages in agriculture. Another phenomenon was when river flooded, damaging many houses and leaving many people without home. The climate is viable and so hot days, heat waves and droughts are possible scenario. These events were responsible for the investment in new methods for water management (World Bank, 2016).

Seychelles, officially Republic of Seychelles, is a group of islands in Indian Ocean and the population is approximately 95,000 citizens. Tourism and fisheries are the sectors that Seychelles' economy is depending on. The main challenge is to minimize the stress on scarce water resources. Not many residents have sewerage systems and the others use septic reservoirs. The systems are not functioning right and thereby these are a source of pollution which transfers diseases through water. Climate change will sharpen water supply and sanitation problems since investigations predict extreme weather conditions such as droughts and floods (Bahri et al., 2016).

Municipality of Marondera in Zimbabwe has population approximately 65.000 inhabitants. The city is characterized by the poor water quality because of pollution, deposition of dangerous chemicals, a serious sanitation situation and a large amount of untreated wastewater. Marondera had a good sewer network, but now it has problems because of inadequate conservation. The access to potable water is only 77% because of lack of experienced personnel (Bahri et al., 2016).

Kinshasa is a city in Democratic Republic of Congo and the population is expecting to reach 17 million inhabitants by 2030. The demand for water will rise. 64% of people

have access to potable water in Kinshasa. Kinshasa's sanitation sector faces many service deficits. 14% of people have access to full sanitation services. Environmental degradation is happening because of poor management of sanitation waste. A large amount of solid waste ends up in rivers. The supply of drinking water and sanitation are challenges for Kinshasa (Bahri et al., 2016).

Australia, officially Commonwealth of Australia, is a country comprising the Australian continent, the island of Tasmania and other islands. It is the biggest country of Oceania. It is highly urbanized, and the population is concentrated on the eastern site. Capital of Australia is Canberra and other big cities are Sydney, Melbourne, Brisbane, Peth and Adelaide. Industrial water use, urban population and expansion of irrigation have increased the demand for water resources. Storm water management and land use is inefficient (Mitchell, 2006). Drought is a problem that Southeast Australia is facing. Drought has put pressure on limited water resources and creates the perception that this is the start of a crucial change (Chiew et al., 2011). IUWM is a tool that can help Australia. In the next chapter 10 Australian areas have already used the principles of IUWM are presented. (Mitchell, 2006)

Rotterdam is the second largest city in Netherlands with population approximately 620,000 citizens. The title of most populated urban area in Europe belongs to Rotterdam city. The city's location is the delta of rivers Rhine and Meuse. There are systems of canals, lakes, waterways, sewers and pumping stations in order to regulate sea level. Rotterdam wants to become a more attractive environment for people to live in. The city seeks ways to improve its image by reinvesting itself as a "water city of the future" (World Bank, 2016).

4.3 Literature review on implemented *IUWM*

Mitchell (2006) examined the implementation of IUWM in Australian urban water and land development industries. The study presents 10 countries of Mitchell's investigation. IUWM utilizes many tools to minimize environmental impacts and provide sustainability. In the following examples of case study IUWM uses mix tools of

water conservation and efficiency, water planning and design, urban landscape and layout, roof runoff, storm water management, wastewater management, rainwater management.

Adelaide in South Australia: The implementation of IUWM takes place in Christine Walk which is a residential area and a community facility. Low water usage of plants, subsurface irrigation systems and communal usage of laundry are some examples that demonstrate the right use of water after the implementation of IUWM. Also, wastewater management and usage of irrigation are implemented practices in Christine Walk. In the same city in another place the implementation of IUWM takes place too. New Heaven Village is a medium size residential area. Storm management, rainwater harvesting, and efficient water supply is used in this area.

Brisbane in Queensland: Carindale Pines is residential area which is examined, and it is characterized by a small number of households. The storm water and rainwater management are tools that are already applicable. This place has rainwater tanks.

Sydney in New South Wales: Homebush Bay is a residential area with medium sized houses but is also a commercial, industrial and sporting facilities area. IUWM features in this area are potable supply, storm water and rainwater management and wastewater treatment in the no potable system. Also, IUWM have implemented and in Rouse Hill which is a low sized residential area. Treated wastewater is used for toilet flushing, garden watering and car washing. Another implementation on IUWM exists in Kogarah Town Square which is a medium sized residential area. Rainwater is utilized for toilet flushing, car washing, and storm water is used for irrigation of open space.

New Castle in New South Wales: Fig Tree Place is a medium size residential area and a redevelopment site. This area is characterized by rainwater reservoirs responsible for supply of hot water and toilet flushing. Ground water is used for irrigation system and it is useful for washing buses at the station. Other features are storm water management and rainwater management.

Albury in New South Wales: Charles Sturt University Thurgoona Campus is a university campus and a home for many students. Grey water is used to control the temperature of building and also is used to wash clothes. Storm water is utilized for landscape irrigation and rainwater plays a significant role in subsurface irrigation and wash of clothes. Other features are wastewater management and rainwater management which provide a good quality of water.

Inkerman D' Lux in Melbourne at Victoria is the last examined place. It is a medium sized residential area. In this area storm water and grey water are used for flushing the toilets and garden irrigation. Furthermore, storm water and rainwater management are already used. Also, in Melbourne IUWM implemented in Reservoir Civic Centre which is a centre providing council and community facilities. Water efficiency is huge in toilets and showers. Rainwater is used for toilet flushing and storm water is used for garden irrigation.

Bahri et al. (2016) examined islands, a mega city and a small city in Africa with the aim to implement the key principles of IUWM.

Seychelles in East Africa face problems with water scarcity resources. The suggested project intends to adopt IUWM features in order to succeed. Reclaimed water is needed for fresh water supply, toilet flushing and for industrial use. Rainwater harvesting is needed too. Also, energy supply and solid waste will be important in evaluation of effects of water supply systems. Storm water management is an important tool for many reasons such as to assess the impact of floods. Water supply, drainage, solid waste and energy are aim to sustainability.

Municipality of Marondera in Zimbabwe is the second examined city by Bahri et al (2016). The management of urban water supply and sanitation services are crucial issues. A greater quality of water for many utilizations such as urban agriculture, green areas and industrial use, are needed. Wastewater management is required for water drains, maintenance of public toilets and nice hygiene practices.

Significant challenge for Kinshasa in Democratic Republic of Congo is to obtain potable supply water and sanitation for all residents. Kinshasa will use the principles of IUWM in order to manage natural resources and urban water. Sanitation, drainage and storm water to the whole city is needed. Storm water management and wastewater management are the future goals for Kinshasa.

Eckart et al. (2011) approaches the implementation of the IUWM in three African cities: Cape Town, Masindi Town and Accra are the three countries that were used.

The challenges of Cape Town could be managed by the IUWM approach. A better water supply system is needed to serve more people with potable water. Reclaimed water will be used to minimize the use of fresh water. Storm water management will be used for urban drainage. Green areas will help storm water to be hold. Blue-green network will be used for recreation reasons. The harvesting of rainwater will be used for many activities.

Accra in Ghana has shown evolution on managing urban water system. There are many features of IUWM that encourages city to find solutions. The use of rainwater harvesting, and grey water reuse can help many facilities. The use of rainwater will avoid the investments in expensive drainage systems. Water reclamation will be utilized for washing vehicles, gardens and flushing toilets. Also, wastewater management, solid waste management and urban drainage planning will be used.

Masindi Town in Uganda with the use of IUWM principles tries to solve the problems of water supply, sanitation, drainage and solid waste. The large amount of rain is a frequent phenomenon for the city. Rainwater harvesting can be considered as an alternative source for many utilizations. The separation of grey water from black water is important. The reused water could be used for gardening and other uses. Industries must manage their wastes and uses reclaim water. So, wastewater treatment, storm water and solid waste management are possible practices.

In 2016 a report was written by World Bank staff and consultants: Martin Gambrill, Meleesa Naughton, Lizmara Kirchner and Amanda Goksu and many others with the aim to use IUWM in Rotterdam and Windhoek.

Rotterdam needs an efficient IUWM system. The IUWM approach could help the city in many ways. At first the separation of clean rainwater from wastewater stream and water storage are important. Alternative ways of retaining and harvesting rainwater are the future goal. A new idea is to build parking garage which use underground water storage facility. Also, another idea is to install green roofs.

Windhoek in Namibia in Sub-Saharan Africa needs some methods to ensure water security. IUWM for this city is focusing on alternative water resources by wastewater management in water supply. Protection, conservation and the use of water at its resources are priorities for the city.

It is observed that Australia is the country that has implemented the IUWM in many cities. Australia is a country with many extreme events in its history. The use of the IUWM helps citizens to have access in water using it in many activities without minimizing the freshwater. Australia is an example of a country that succeeded that innovative approach. On the other hand, Africa is in need for utilization of the principles of IUWM. Many regions suffer from water scarcity problems. Africa has researched ways to use it in the cities. The project of IUWM will help cities with modern ways to provide good quality water supply to most of the people. Another example of a city that has as a plan to use IUWM is Rotterdam. Rotterdam authorities want to adapt the principles of IUWM because are experts in dealing with water issues, while also this implementation will bring a glamour attitude. Africa, Australia and Rotterdam have different needs and thereby the use of IUWM is about to compete different goals.

Table 4.3.2: IUWM features in cities

Author's name	Year	Continent	Country	City	Land use	IUWM features	Development type
Mitchell	2006	Oceania	South Ausrtalia	Adelaide	Residential	Water efficiency,	Implementation

						water supply, wastewater treatment, storm water management	
Mitchell	2006	Oceania	Queensland	Brisbane	residential	Water efficiency, water supply, rainwater management, storm water management,	Implementation
Mitchell	2006	Oceania	New South Wales	Sydney	Residential Commercial Industrial other	Water supply, rainwater management, storm water management, wastewater management, water efficiency, storm water management	Implementation
Mitchell	2006	Oceania	New South Wales	Newcastle	residential	Water supply, rainwater management, storm water management, rainwater management, wastewater management	Implementation
Mitchell	2006	Oceania	New South Wales	Albury	Residential Commercial	Water efficiency, water supply, storm water management, rainwater management, wastewater management	Implementation
Mitchell	2006	Oceania	Victoria	Melbourne	Residential Commercial	Water supply, rainwater management, storm water management	Implementation
Mitchell	2006	Oceania	South Ausrtalia	Adelaide	Residential	Water supply, storm water management, rainwater harvesting	Implementation
Mitchell	2006	Oceania	New South Wales	Sudney	Residential	Water supply, storm water management, rainwater harvestig	Implementation
Mitchell	2006	Oceania	New South Wales	Sydney	Residential, commercial, retail and municipal land uses	Water supply, storm water management	Implementation
Mitchell	2006	Oceania	Victoria	Melbourne	Public	Water supply,	Implementation

						storm water management, rainwater harvesting	
Bahri, Brikke & Vairavamoorthy	2016	Africa	East Africa	Seychelles	Residential	Water supply, energy supply and solid waste, storm water management	Without implementation yet
Bahri, Brikke & Vairavamoorthy	2016	Africa	Zimbabwe	Municipality of Marondera	Residential	Water supply and sanitation, wastewater management	Without implementation yet
Bahri, Brikke & Vairavamoorthy	2016	Africa	Democratic Republic of Congo	Kinshasa	Residential	Water supply and sanitation, storm water management, solid waste management, wastewater management	Without implementation yet
Eckart J., Ghebremichael K., Khatri K., Mutikanga H., Sempewo J., Tsegaye S. & Vairavamoorthy K.	2011	Africa	South Africa	Cape Town	residential	Water supply, rainwater harvesting, storm water management	Without implementation yet
Eckart J., Ghebremichael K., Khatri K., Mutikanga H., Sempewo J., Tsegaye S. & Vairavamoorthy K.	2011	Africa	Ghana	Accra	Residential	Water supply, rainwater harvesting, water reuse and reclamation, wastewater management	Without implementation yet
Eckart J., Ghebremichael K., Khatri K., Mutikanga H., Sempewo J., Tsegaye S. & Vairavamoorthy K.	2011	Africa	Uganda	Masindi Town	Residential	Water supply, rainwater harvesting, wastewater management, storm water and solid waste management	Without implementation yet
World Bank staff and consultants	2016	Africa	Namibia	Windhoek	Residential	Water supply, wastewater management	Without implementation yet
World Bank staff and consultants	2016	Europe	Netherlands	Rotterdam	Residential	Water supply, Rainwater harvesting	Without implementation yet

4. Conclusion

Climate change affects the water sector due to extreme weather events such as droughts, floods and generates problems in water quality. Cities' role to handle with climate change is really significant since human activity is the main reason that has caused this phenomenon. Climate change and cities are related directly. Because of the global warming cities face issues with water quality, water supply and sanitation. Governments and stakeholders are concerned about the situation and are trying to find a sustainable solution. Water management systems are critical for handling the water scarcity.

In this study the promising approach, of the integrated urban water management (IUWM) that creates a better situation with the aim to deal with issues those cities face in water sector. Urban water management have failed to complete the cities' demands. Urban water management is out of date and it is replaced by the innovative approach of IUWM.

According to literature review Australia succeed to implement IUWM in many areas. Australia provides better water quality and water supply to its citizens. There are many uses of treated water that help the community to find a solution with water scarcity due to the utilization of IUWM system. Of course, more cities in Australia must adopt this approach of water management. It is a fact that the bases have set not only for Australia, but also these implementations are a guide for every other city which faces similar water issues. On the other hand, Africa is a large continent with numerous water issues. Through research Africa understood that a vital solution is the utilization of the principles of IUWM. There are many scientific researches advocating this use. If government and stakeholders work together this implementation will became true. Netherlands because of its situation is an expert in water management. Rotterdam's

goal is to implement IUWM in the future. Rotterdam authorities know when a project is innovative and suitable for the city and that is the reasons that want it to be used. The city understands the benefits of that usage and why it is an advocator of IUWM.

There are many studies that inferred the use of IUWM in cities but studies which describe that implementation are rare. Countries with implementation of IUWM must provide the documents in order to help other cities to use it. On the other hand, there are many papers that focus on how cities will utilize the concept of IUWM. Many countries have published their research about the way that they will use IUWM and which features of this concept there are going to use.

IUWM is a new and innovative approach. More cities must consider its implementation because the advantages are obvious. World faces severe water problems and many people do not want to admit it. Many people have not yet face water issues and other faces only a part of the problem. Stakeholders should look ahead in order to avoid future problems. This could happen whether government and stakeholders start a research on how they cool adjust IUWM in their country before it is too late. On the other hand, there are cities that face serious water problems and they have not considered the idea of applying IUWM. These cities must learn about the benefits and try to adopt it with the aim to offer to their citizens a sustainable way of life.

Bibliography

Alcamo, J., Flörke, M., & Märker, M. (2007). Future long-term changes in global water resources driven by socio-economic and climatic changes. *Hydrological Sciences Journal*, *52*(2), 247-275.

Arnell, N. W., & Delaney, E. K. (2006). Adapting to climate change: public water supply in England and Wales. *Climatic Change*, *78*(2-4), 227-255.

Bahri, A. (2012). Integrated urban water management. *The Background Papers. Global Water Partnership (GWP) Technical Committee (TEC), Stockholm, Sweden*.

Bahri, A., Brikke, F., & Vairavamoorthy, K. (2016). Managing change to implement integrated urban water management in African cities.

Barbosa, A. E., Fernandes, J. N., & David, L. M. (2012). Key issues for sustainable urban stormwater management. *Water Research*, *46*(20), 6787-6798.

Bates, B., Kundzewicz, Z. W., Wu, S., Burkett, V., Doell, P., Gwary, D., Hanson, C., Heij, B., Jiménez, B., Kaser, G., Kitoh, A., Kovats, S., Kumar, P., Magadza, C. H. D., Martino, D., Mata, L., Medany, M., Miller, K. & Arnell, N. 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Chang

Boers, T. M., & Ben-Asher, J. (1982). A review of rainwater harvesting. *Agricultural Water Management*, *5*(2), 145-158.

Brown, R. R. (2005). Impediments to integrated urban stormwater management: the need for institutional reform. *Environmental Management*, *36*(3), 455-468.

Bulkeley, H. (2013). Cities and Climate Change. London: Routledge, https://doi.org/10.4324/9780203077207

Chasek, P. S., Downie, D. L., & Brown, J. W. (2010). Global Environmental Politics (ed.).

Chiew, F. H. S., Young, W. J., Cai, W., & Teng, J. (2011). Current drought and future hydroclimate projections in southeast Australia and implications for water resources management. *Stochastic Environmental Research and Risk Assessment*, *25*(4), 601-612

Chocat, B., Krebs, P., Marsalek, J., Rauch, W., & Schilling, W. (2001). Urban drainage redefined: from stormwater removal to integrated management. *Water Science and Technology*, *43*(5), 61-68.

Corcoran, E. (Ed.). (2010). *Sick water? the central role of wastewater management in sustainable development: a rapid response assessment*. UNEP/Earthprint.

Delpla, I., Jung, A. V., Baures, E., Clement, M., & Thomas, O. (2009). Impacts of climate change on surface water quality in relation to drinking water production. *Environment international*, *35*(8), 1225-1233.

Distefano, T., & Kelly, S. (2017). Are we in deep water? Water scarcity and its limits to economic growth. *Ecological Economics*, *142*, 130-147.

Eckart J., Ghebremichael K., Khatri K., Mutikanga H., Sempewo J., Tsegaye S. & Vairavamoorthy K. 2011, J. The Future of Water in African Cities. Why Waste Water? In: DEVELOPMENT, D. I. D. E. A. S. (ed.).

Ercin, A. E., & Hoekstra, A. Y. (2014). Water footprint scenarios for 2050: A global analysis. *Environment International*, *64*, 71-82.

Fattahi, P., & Fayyaz, S. (2010). A compromise programming model to integrated urban water management. *Water Resources Management*, *24*(6), 1211-1227.

GWP (Global Water Partnership) TAC (Technical Advisory Committee). 2000. Integrated Water Resources Management. TAC Background Paper No. 4. Global Water Partnership, Stockholm.

Habitat, U. N. (2011). Cities and climate change: Global report on human settlements 2011. *London: Earthscan*.

Hellström, D., Jeppsson, U., & Kärrman, E. (2000). A framework for systems analysis of sustainable urban water management. *Environmental impact assessment review*, *20*(3), 311-321.

Hvitved–Jacobson, T., & Yenisei, Y. A. (1991). Highway runoff quality, environmental impacts and control. In *Studies in Environmental Science* (Vol. 44, pp. 165-208). Elsevier.

Hvitved-Jacobsen, T., Vollertsen, J., & Nielsen, A. H. (2010). Fundamentals of Urban Highway Stormwater Pollution. In *Urban and Highway Stormwater Pollution* (pp. 1-20). Taylor & Francis.

Iglesias, A., Garrote, L., Flores, F., & Moneo, M. (2007). Challenges to manage the risk of water scarcity and climate change in the Mediterranean. *Water resources management*, *21*(5), 775-788.

Karagiannis, I. C., & Soldatos, P. G. (2008). Water desalination cost literature: review and assessment. *Desalination*, *223*(1-3), 448-456.

Kayaga, S., & Smout, I. K. (2008). Water demand management: a key building block for sustainable urban water management.

Lazarova, V., Levine, B., Sack, J., Cirelli, G., Jeffrey, P., Muntau, H. & Brissaud, F. (2001). Role of water reuse for enhancing integrated water management in Europe and Mediterranean countries. *Water Science and Technology*, *43*(10), 25-33.

Mackay, R., & Last, E. (2010). SWITCH city water balance: a scoping model for integrated urban water management. *Reviews in Environmental Science and Bio/Technology*, *9*(4), 291-296.

Makropoulos, C. K., Natsis, K., Liu, S., Mittas, K., & Butler, D. (2008). Decision support for sustainable option selection in integrated urban water management. *Environmental modelling & software*, *23*(12), 1448-1460.

Mara, D. D. (2003). Water, sanitation and hygiene for the health of developing nations. *Public health*, *117*(6), 452-456.

Miller, G. W. (2006). Integrated concepts in water reuse: managing global water needs. *Desalination*, *187*(1-3), 65-75.

Mitchell, V. G. (2006). Applying integrated urban water management concepts: a review of Australian experience. *Environmental management*, *37*(5), 589-605.

Moe, C. L., & Rheingans, R. D. (2006). Global challenges in water, sanitation and health. *Journal of water and health*, *4*(S1), 41-57.

Montgomery, M. A., & Elimelech, M. (2007). Water and sanitation in developing countries: including health in the equation.

Murray, S. J., Foster, P. N., & Prentice, I. C. (2012). Future global water resources with respect to climate change and water withdrawals as estimated by a dynamic global vegetation model. *Journal of Hydrology*, *448*, 14-29.

Palaniappan, M., Gleick, P. H., Allen, L., Cohen, M. J., Christian-Smith, J., Smith, C., & Ross, N. (2010). Clearing the waters: a focus on water quality solutions.

Parkinson, J., & Tayler, K. (2003). Decentralized wastewater management in peri-urban areas in low-income countries. *Environment and Urbanization*, *15*(1), 75-90.

Seckler, D., Barker, R., & Amarasinghe, U. (1999). Water scarcity in the twenty-first century. *International Journal of Water Resources Development*, *15*(1-2), 29-42.

Tucci, C. E. M. (2009). Integrated urban water management in large cities: a practical tool for assessing key water management issues in the large cities of the developing world. *World Bank*.

UNDP (United Nations Development Program). 2006. Human Development Report 2006. Beyond Scarcity: Power, poverty and the global water crisis. UNDP, New York.

World Bank. 2016. Mainstreaming Water Resources Management in Urban Projects: Taking an Integrated Urban Water Management Approach. Washington DC.

World Health Organization. (2006). Meeting the MDG drinking water and sanitation target: the urban and rural challenge of the decade.

Whitehead, P. G., Wilby, R. L., Battarbee, R. W., Kernan, M., & Wade, A. J. (2009). A review of the potential impacts of climate change on surface water quality. *Hydrological Sciences Journal*, *54*(1), 101-123.

Whitler, B. J., & Warner, J. (2014). Integrated urban water management for planners. *PAS Memo*, (October), 13.